DIRECT METHANOL, LIQUID-FEED FUEL CELL PROGRESS AND PROSPECTS

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direct oxidation

proton exchange membrane

PEM

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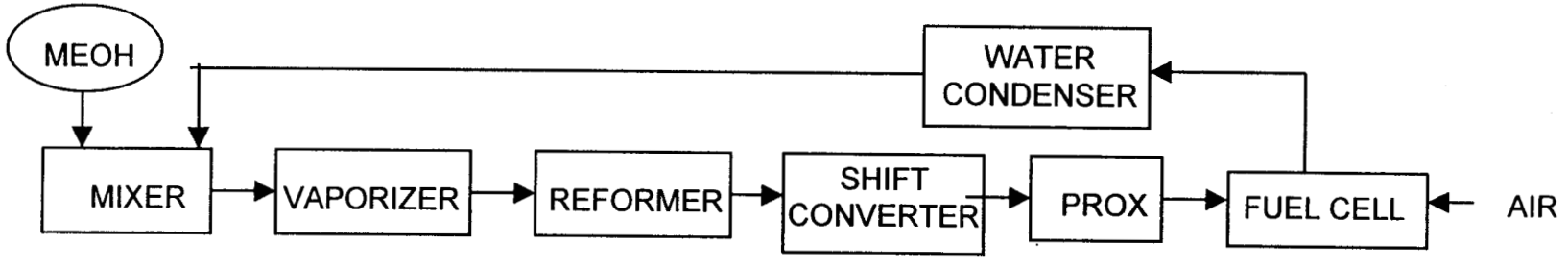
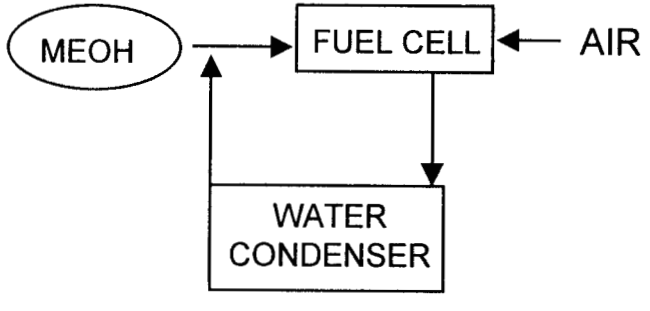
COMPARISON OF DIRECT AND INDIRECT METHANOL FUEL CELL OPERATION

INDIRECT METHANOL FUEL CELL SYSTEM



DIRECT METHANOL FUEL CELL SYSTEM



DIRECT OXIDATION

1. REDUCES COMPLEXITY
2. REDUCES WEIGHT BY 25%-50%
3. IMPROVES RELIABILITY
4. REDUCES COST

JPL

DIRECT METHANOL FUEL CELL SYSTEM ADVANTAGES

ABSENCE OF POLLUTANTS

- H_2O AND CO_2 ARE THE ONLY PRODUCTS

COMPARED TO H_2/O_2 FUEL CELLS DIRECT REACTION OF METHANOL SIMPLIFIES FUEL SYSTEM

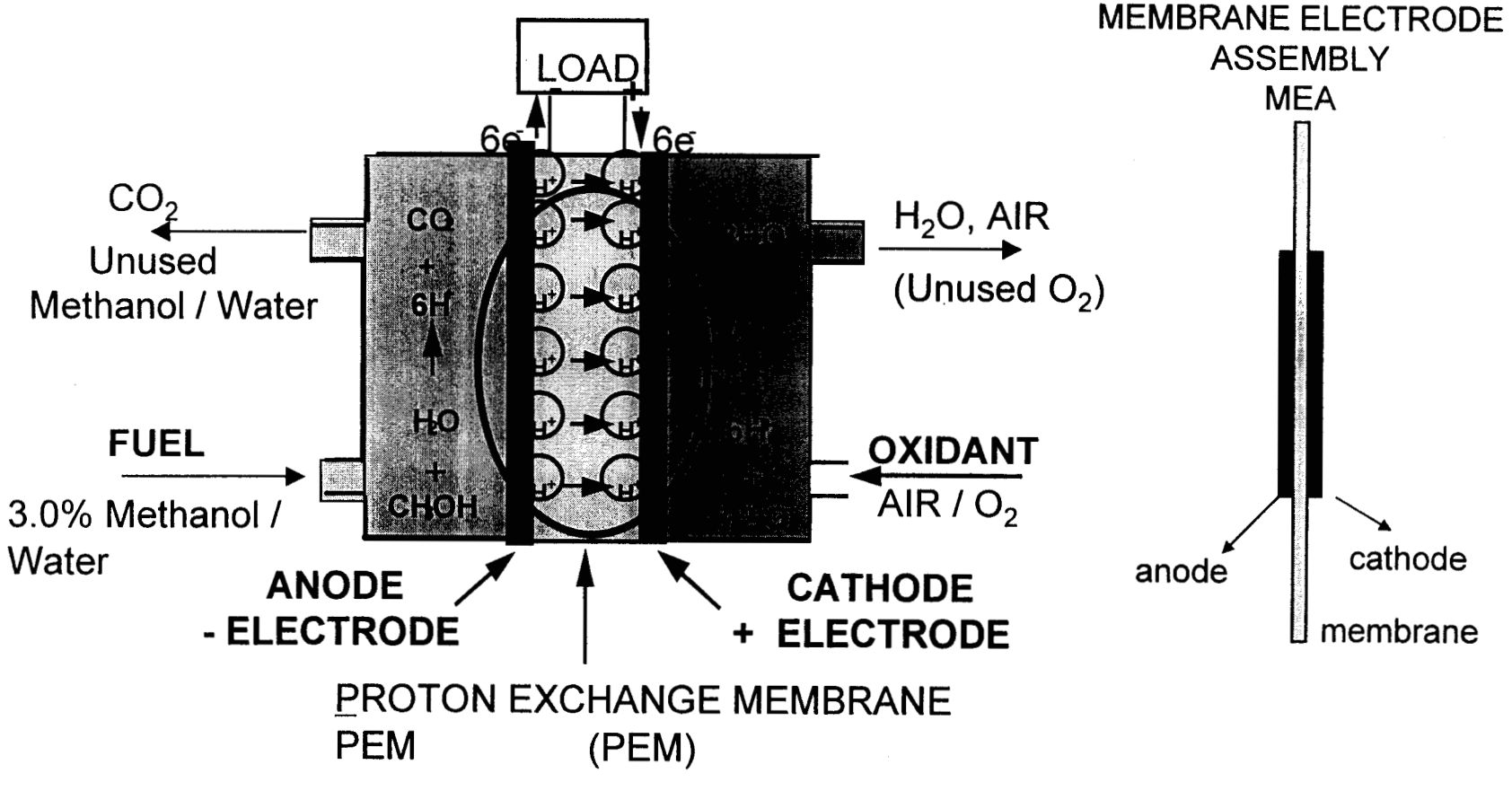
- ELIIMINATES HIGH PRESSURE HYDROGEN STORAGE
- ELIMINATES REFORMER TO CONVERT METHANOL TO H_2
- NO WARMUP PROBLEMS AND SLUGGISH RESPONSE
- ELIMINATES HYDRIDE STORAGE

LIQUID FEED OF METHANOL

- REDUCES STACK COMPLEXITY (E.G. COOLING PLATES)
- CONVENIENT FUEL DELIVERY AND STORAGE
- LIQUID FUEL MIX PREVENTS SEPARATOR DRYOUT

OPERATION POSSIBLE AT ROOM TEMPERATURE

DIRECT METHANOL FUEL CELL SCHEMATIC



DIRECT METHANOL, LIQUID-FEED FUEL CELL REACTIONS

Anode $CH_3OH + H_2O = CO_2 + 6H^+ + 6e^-$

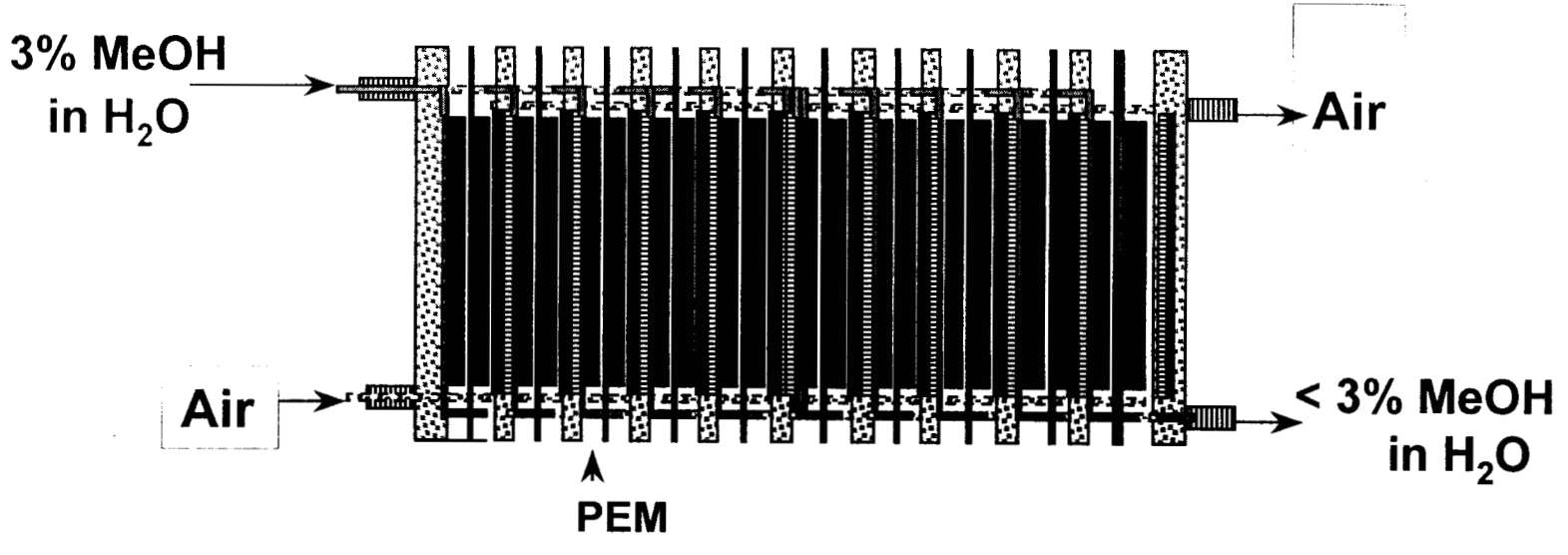
Cathode $6H^+ + 3/2O_2 + 6e^- = 3H_2O$

Net Reaction $CH_3OH + 3/2\ O_2 = CO_2 + 2H_2O$

1 LITER OF CH_3OH CAN PRODUCE ~ 5.0 KWh

34% (1.7 KWh) ACHIEVED THUS FAR

PROJECTIONS FOR 1.2 KW DMFC STACK



INTERNALLY MANIFOLDED
LOW PRESSURE
~6 CELLS / INCH
COMPOSITE MOLDED BIPLATES

1.2 KW @60^{0}C, 2.4 KW @ 90^{0}C
VOLTAGE ~16v
CELLS ~35
DIMENSIONS 27CM X 27CM X 14CM

PERFORMANCE IMPROVEMENT

FUEL: 3%(l m) MEOH, 90°C, AIR AT 20 PSIG, 4" x 6" ELECTRODE AREA

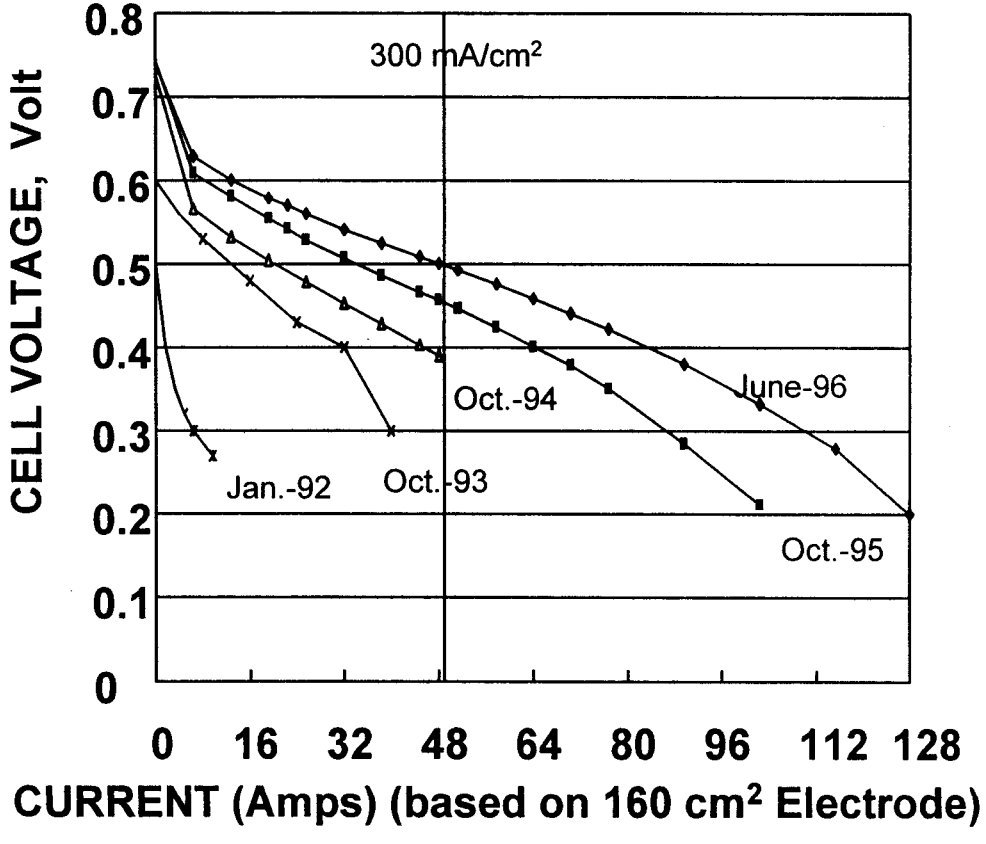
ADVANCES DUE TO

IMPROVEMENTS IN CATALYST COMPOSITION

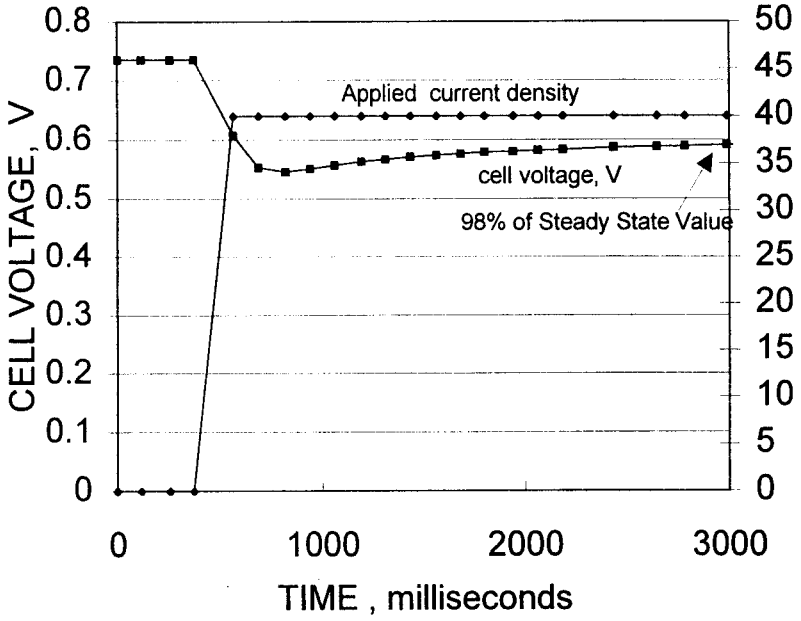
IMPROVEMENTS IN ELECTRODE STRUCTURE

IMPROVEMENTS TO CATALYST / ELECTRODE /MEMBRANE INTERFACE

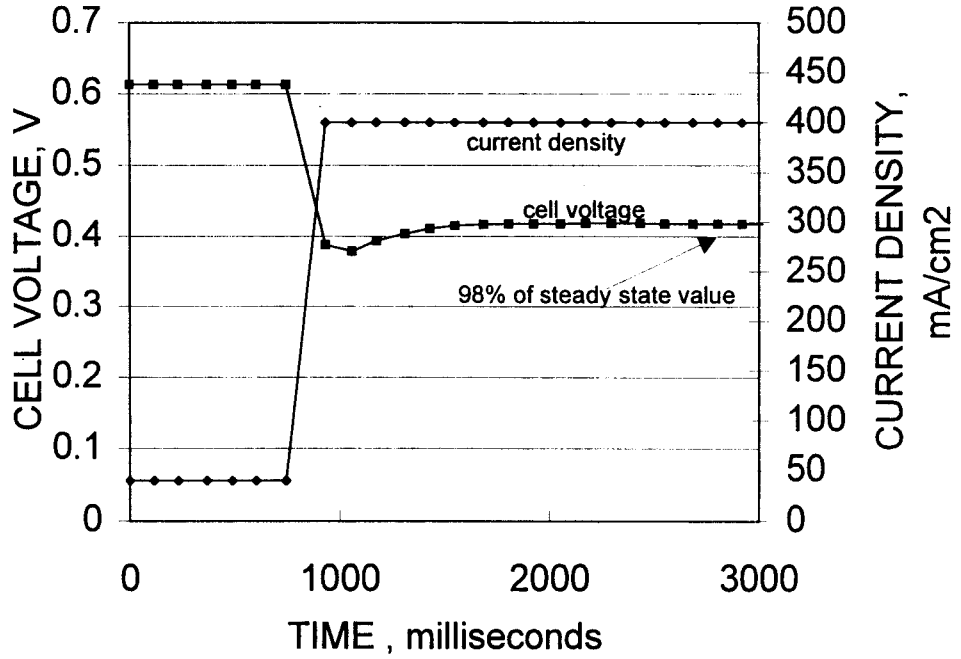
IMPROVEMENTS IN PROCESSING CATALYST



LOAD HANDLING CHARACTERISTICS



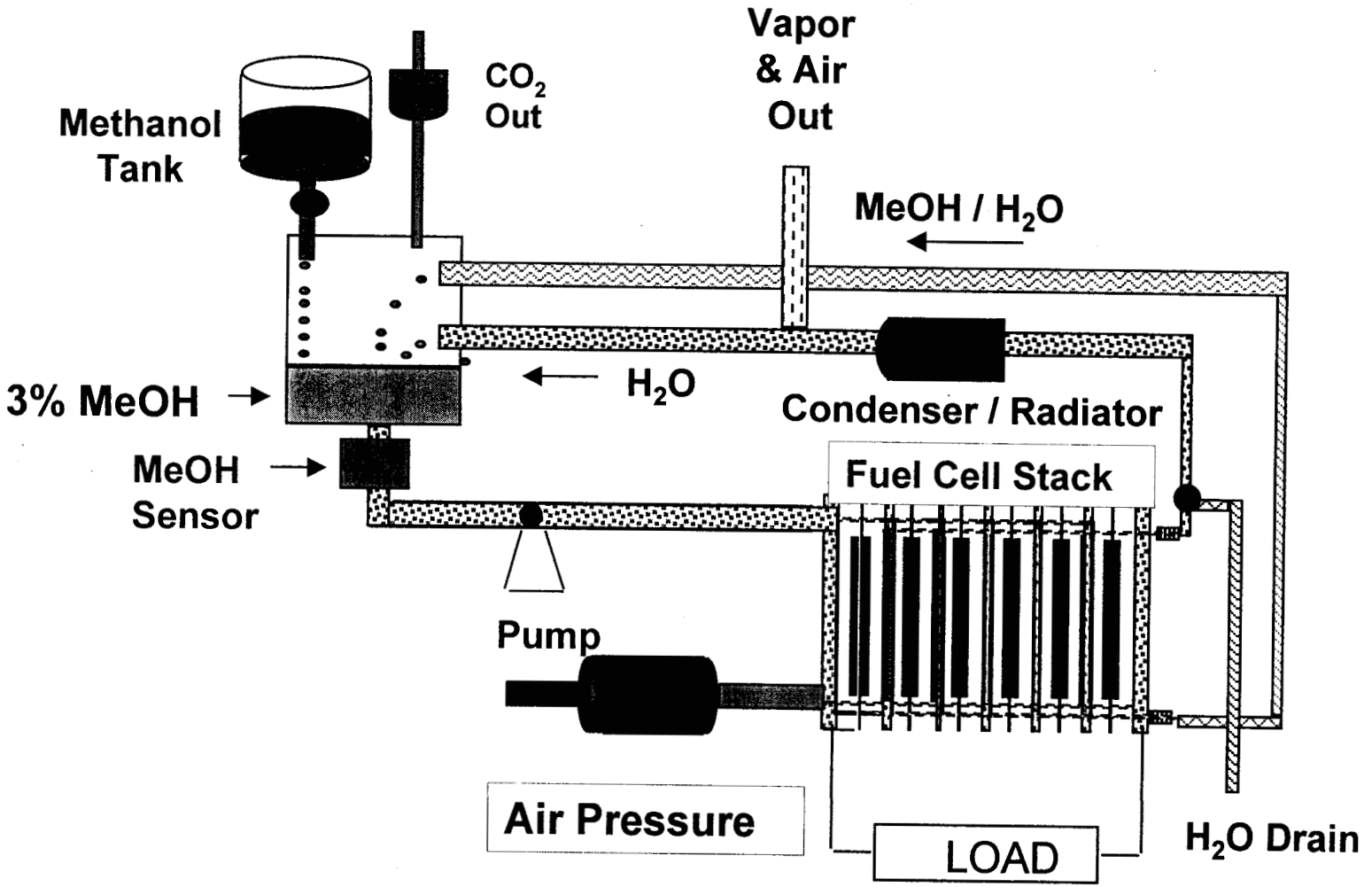
- Good Transient Response in the 0-500 ms range.



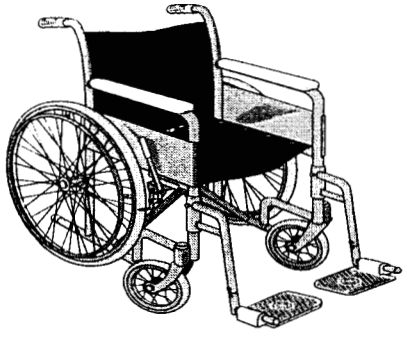
SUMMARY OF ADVANCES

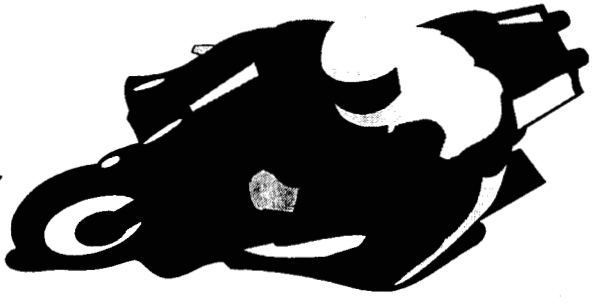
- Demonstrated Power Densities of 230 mw/cm^2
  (100 Amps on 4" x 6" electrode area)
- Demonstrated system operation at 50W level
- Developed an Demo'd Low Concentration MeOH Sensor
- Demonstrated Excellent Load Following
- Demonstrated Stable Catalyst Performance
  >400 Hours of Intermittent Operation
- New Methods for Layering Catalysts
  Reduces catalyst and cost
- New Proton Exchange Membrane
  Increased Efficiency to >45% and Reduced Cost
- Developed Model for Complete 150W System
  DARPA 150W System Demonstration 9/99

DIRECT METHANOL FUEL CELL SYSTEM CONCEPT

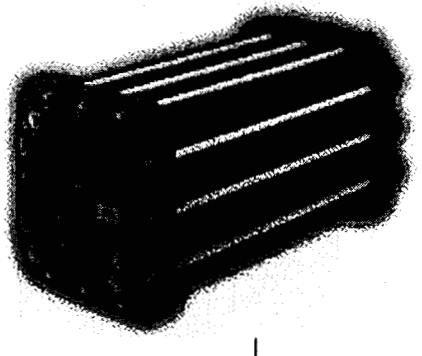


TRANSPORTATION APPLICATIONS FOR THE JPL DIRECT METHANOL FUEL CELL



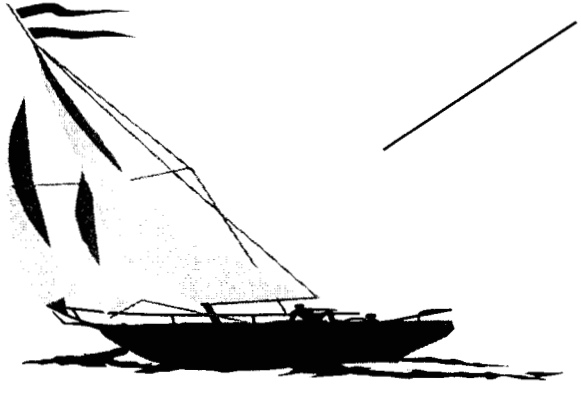


CO_2



Methanol + Air

POLUTION-FREE POWER



Water

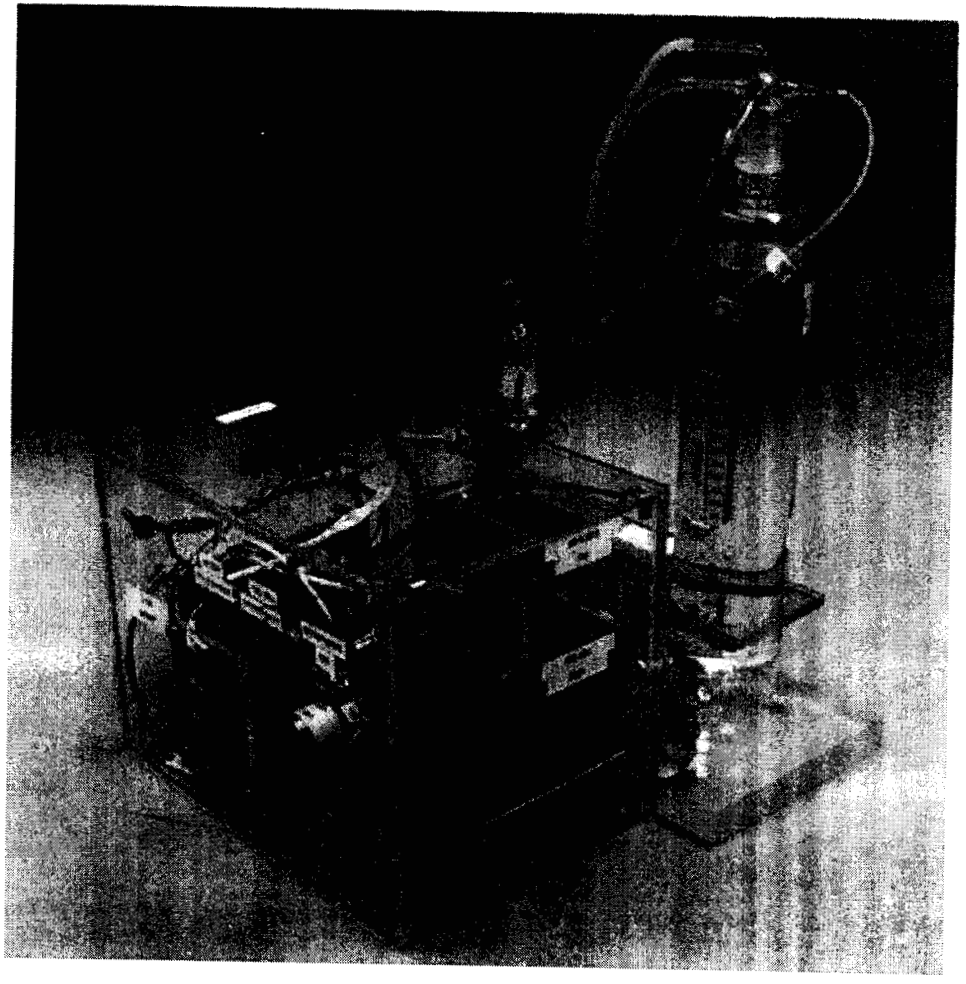
APPLICATIONS FOR THE DIRECT METHANOL, LIQUID-FEED FUEL CELL

NEAR TERM

SAIL / POWER BOATS
EMERGENCY POWER
GOLF CARTS
PEOPLE MOVERS
AIRPORT VEHICLES
FACTORY TRUCKS
LAWN MOWERS

DIRECT METHANOL FUEL CELL VEHICLES

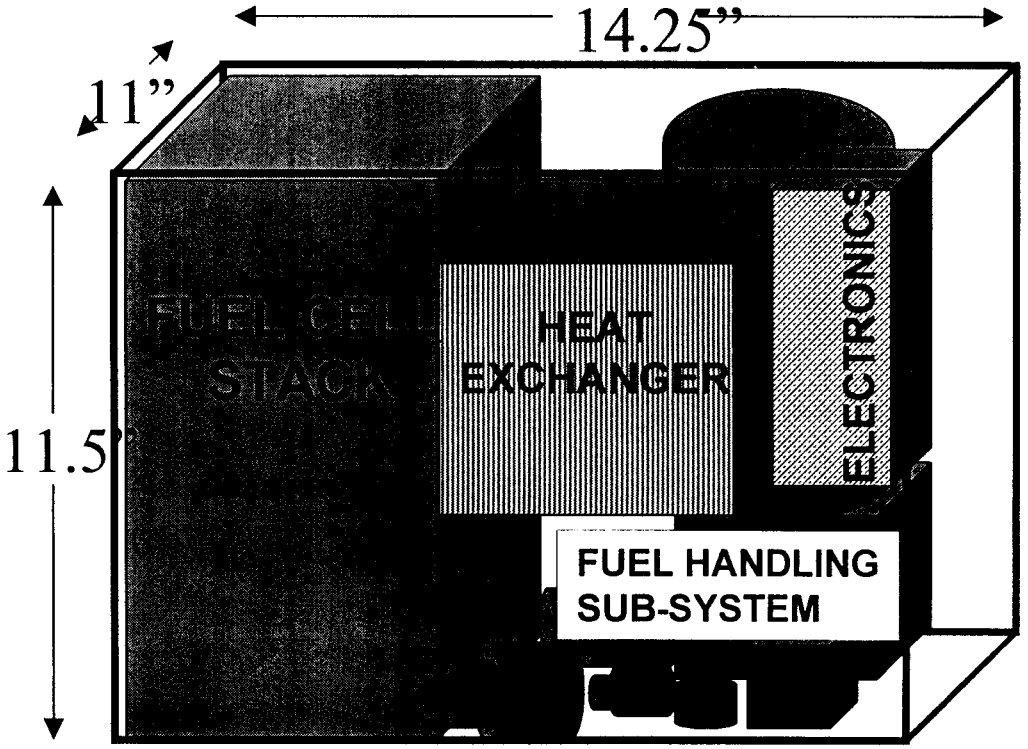
ARDEC HYBRID METHANOL SYSTEM



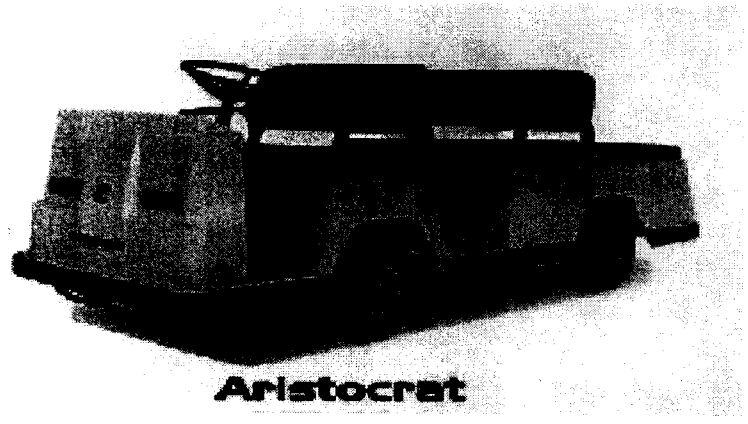
DARPA 150 WATT FUEL CELL SYSTEM

CHARACTERISTICS

POWER	150 W
CAPACITY	5000 WH
VOLTAGE	24V
CURRENT	6.25A
MASS (W FUEL)	12 KG
VOL.	30 LITERS
OP. TEMP.	15-42°C
START -UP	< 1 MIN.



DIRECT METHANOL 2.3 KW FUEL CELL SYSTEM IN A LIGHT DUTY VEHICLE APPLICATION



PEOPLE-MOVER	
LOAD CAPACITY	1600 LBS
BED VOLUME	253 LITERS
SYS. VOL.	80 LITERS
MASS	118 KG
MEOH TANK	10LITERS
ENERGY	12.3 KWH
CONT. OPER.	10 HRS

Projected Advances in Performance with Air at 300 mA/cm2 & 90C

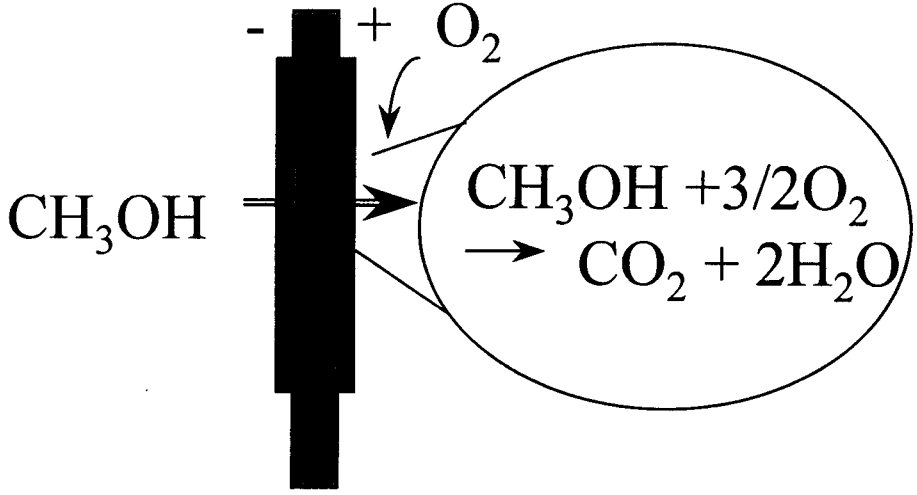
METHANOL THEORETICAL ENERGY = 5kWh / LITER

1998 *State-of-Art*	*2000* *Reduce X-Over with New Membrane*	*2002* *Reduce X-Over & Improve MEA*
0.50 Volts	0.55 Volts	0.60 Volts
42% Voltage Efficient	46%Voltage Efficient	50% Voltage Efficient
80% Fuel Efficient	90% Fuel Efficient	95% Fuel Efficient
34% Overall	41% Overall	48% Overall
(1.7 kWh / L)	(2 kWh / L)	(2.25 kWh / L)

With Lower Crossover, Can Use Higher MeOH Concentration

→ Higher Current Projected

METHANOL CROSSOVER AND ITS IMPLICATIONS



Implications:

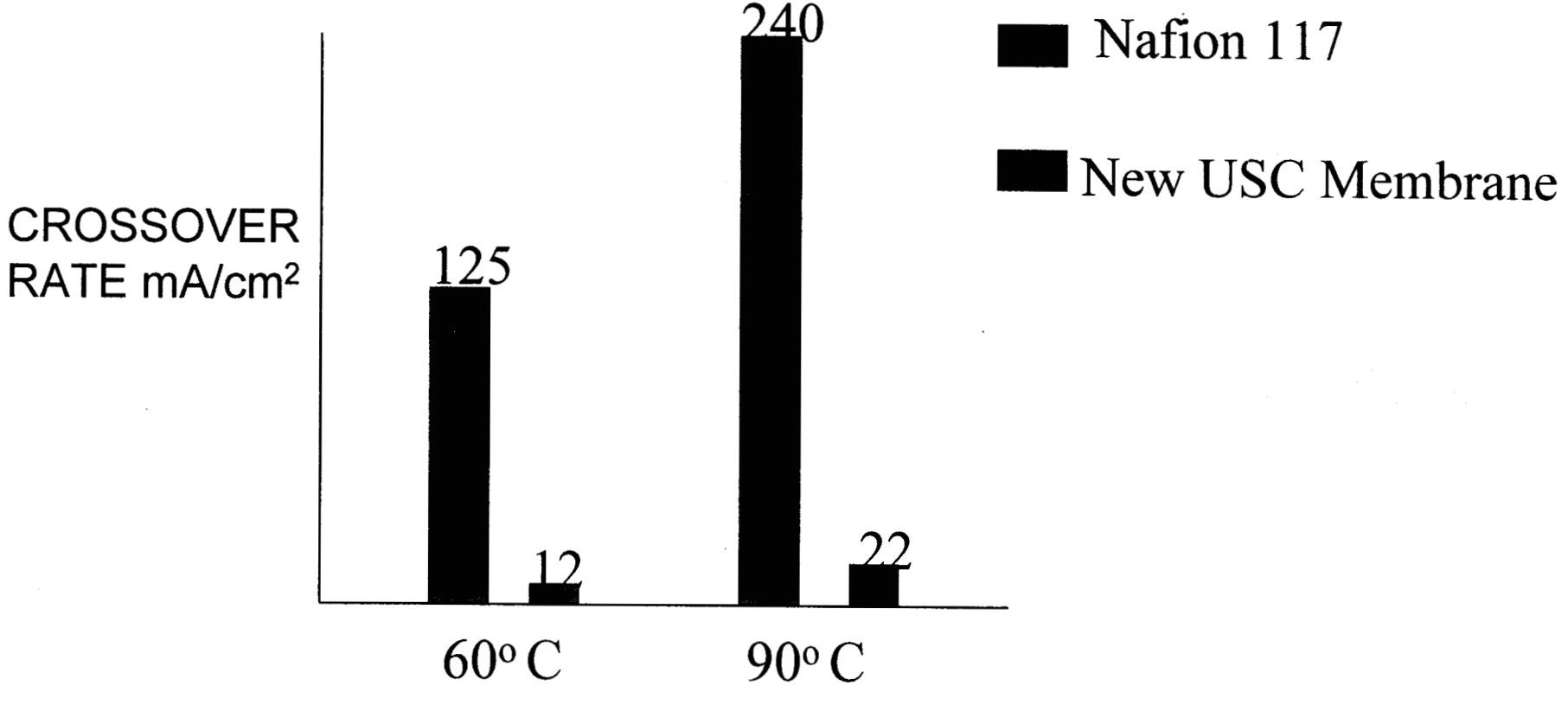
Parasitic fuel loss;20%

Lower cell voltage; by 0.1V

Increased air demand

Reduction in efficiency

MEMBRANES WITH LOW METHANOL CROSSOVER RATE



New membranes have about 10% of the crossover observed with Nafion 117, and ionic conductivity similar to Nafion11100

DIRECT METHANOL FUEL CELL CHALLENGES AND RESOLUTIONS

- **Reduce Methanol Crossover to Increase Efficiency**
  - Solution - USC Membrane Cuts Crossover From 20- 5%
  - Efficiency Increased from 34 to 45%
- **Water Accumulation And Removal**
  - Solution - New Flow Fields & Materials Solve Problem
- **Catalyst Preparation Is Time Consuming**
  - Solution - Engineering / Manufacturing Scale-Up Will Reduce Process Time
- Manufacturer Needed to Initiate Pilot Operation
  - Several Have shown Interest
  - Exclusive License Exists

A FINAL THOUGHT FOR YOUR CONSIDERATION

THE TECHNOLOGY IS READY

THE APPLICATIONS EXIST

THE ENVIRONMENT AWAITS

THE CHALLENGE IS FOR INDUSTRY TO MOVE IT INTO COMMERCIALIZATION

SUMMARY

- METHANOL FUEL CELLS HAVE APPLICATION OVER A WIDE POWER RANGE FROM LOW WATTS TO KILOWATTS

- METHANOL IS A CONVENIENT FUEL THAT IS EASY TO HANDLE AND STORE

- THE DIRECT METHANOL FUEL CELL IS LESS COMPLICATED, EASIER TO OPERATE, AND MORE COMPACT THAN THE COMPETING TECHNOLOGY

- MAJOR ADVANCES IN MEA TECHNOLOGY HAVE RESULTED IN SIGNIFICANT PERFORMANCE IMPROVEMENT

- LOW CROSSOVER MEMBRANE PROMISES FURTHER ADVANCES IN PERFORMANCE AND EFFICIENCY